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A Computer-Simulation-Oriented Design Procedure for a Robust and Feasible Job Shop Manufacturing System, Liang-Hsuan Chen, Yiau-Hweui Chen, pp. 1-10

This paper presents a computer-simulation-oriented design procedure for a robust and feasible job shop manufacturing system based on the Taguchi approach and response surface methodology. The procedure includes optimal region investigation, optimal settings determination, and an adjustment procedure. The steepest descent technique finds the optimal region based on a weighted aggregated design measure. Then optimal settings are resolved and examined in an adjustment procedure to improve robustness. The proposed approach finally determines optimal settings so that the designed system is robust in production and economically feasible. A computer simulation example shows the applicability of the proposed approach.

Keywords: Robust Design, Feasible Design, Taguchi Approach, Response Surface Methodology, Job Shop Manufacturing, Weighted Aggregated Design Measure

Application of Fuzzy Reasoning to a Surface Treatment Process, L.P. Khoo, H.Y. Yeong, L.E. Tang, pp. 11-19

This paper presents work on the establishment of a prototype fuzzy controller for an electroless nickel plating process. Various factors involved in the process were analyzed. The prototype system developed was able to sample information such as pH level and bath temperature from the process and to suggest the most desirable action to be taken. Using this prototype system, it was possible to achieve a relatively stable nickel plating thickness. Details of the prototype system are discussed.

Keywords: Electroless Nickel Plating, Fuzzy Controller, Fuzzy Reasoning, Decision Making

A Methodology for Manufacturing Process Signature Analysis, Steven D. Eppinger, Christopher D. Huber, Van H. Pham, pp. 20-34

Improvement of control systems entails collection of more information about the process and/or more effective use of that information. We present manufacturing process signature analysis to construct a relationship between collected information (process signatures) and the quality of process output, which can be used for on-line monitoring and control. The general procedure consists of feature extraction, feature selection, and classification.

Extraction of large sets of features from signatures is straightforward, and several classification schemes are available, with neural networks being the most general and powerful. Feature selection, however, is generally quite difficult for complex data structures. We present several feature extraction methods and show that neural networks can be useful in choosing different feature sets. Using a data set from an automated solder joint inspection system, we demonstrate the unique capabilities of neural networks for both feature selection and classification, using more traditional statistical classification techniques as a benchmark.

Keywords: Manufacturing Process Monitoring, Feature Selection, Manufacturing Process Signature Analysis, Neural Network Applications

Merits of the Production Volume Based Similarity Coefficient in Machine Cell Formation, Hamid Seifoddini, Manocher Djassemi, pp. 35-44

In this paper, two types of similarity coefficients are compared: (1) the Jaccard's coefficient and (2) the production volume based coefficient. Each is used to form a cellular manufacturing system whose performance will be used as a measure of effectiveness of the similarity coefficient. The sum of intercellular and intracellular material handling costs is used as a criterion for performance evaluation.

Keywords: Cellular Manufacturing, Machine-Cell Formation, Similarity Coefficient Method, Group Technology

Industrial Perspective on Research Needs and Opportunities in Manufacturing Assembly, Louis A. Martin-Vega, Harold K. Brown, Wade H. Shaw, Thomas J. Sanders, pp. 45-58

This paper investigates whether investments in research and development (R&D) could have a significant impact on reducing the cost and/or enhancing the effectiveness of manufacturing assembly. It also recommends a research agenda that from an industrial perspective would result in the highest return on investment in assembly R&D. The assessment was conducted on 24 product lines across companies ranging in size from $10 million to $2 billion in annual sales. Approximately 64% of the assembly dollar value surveyed corresponded to Department of Defense (DoD) products.

A needs and trends analysis was conducted to determine the perception of industrial participants regarding their current investment, need for investment, and cost impact potential of assembly activities. This resulted in identification of three major assembly issues: R&D opportunities, R&D inhibitors, and technology transfer. These findings are also summarized.

Keywords: Assembly, Assessment, Research and Development, Needs, Opportunities, Industrial Survey, DoD, Design for Assembly

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Manufacturing System Performance Sensitivity to Selection of Product Design Metrics, Lissa Galbraith, Timothy J. Greene, pp. 71-79

How and to what level the choice of design metrics influences manufacturing system performance measures is examined for three different types of manufacturing systems. The manufacturing systems were modeled using digital simulation for an electronics assembly case study. The design metrics examined were: (1) part density, (2) part variety, and (3) level of automation. System performance was evaluated using: (1) percentage of time for value-adding process functions, (2) production rate, and (3) nonconformance ratio. Regression modeling suggested that design metrics which affect quality influenced system performance measures the most. The design metric having the highest impact was the level of automation.

Keywords: Production System Design, Production Line, Assembly Line, Performance Measures, Product Design

On-Line Monitoring of Tool Breakage in Face Milling Using a Self-Organizing Neural Network, T.J. Ko, D.W. Cho, M.Y. Jung, pp. 80-90

This study introduces a new tool breakage monitoring methodology consisting of an unsupervised neural network combined with an adaptive time-series modeling algorithm. Cutting force signals are modeled by a discrete autoregressive model in which parameters are estimated recursively at each sampling instant using a parameter-adaptation algorithm based on a recursive least square. The experiment shows that monitoring the evolution of autoregressive parameters during milling is effective for detecting tool breakage. An adaptive resonance network based on Grossberg's adaptive resonance theory (ART2) is employed for clustering tool states using model parameters, and this network has unsupervised learning capability. This system subsequently operates successfully with a fast monitoring time in a wide range of cutting conditions without a priori knowledge of the cutting process.

Keywords: Milling Process, Adaptive Signal Processing, Tool Breakage, Feature, Self-Organizing Neural Network

Implementation of Low-Volume FMS for Prismatic Components, T. Hanada, B.P. Bandyopadhyay, T. Hoshi, pp. 91-108

Fixture preparation and NC data generation are unavoidable operations for effective implementation of flexible manufacturing systems in high product mix and low-volume prismatic components. By developing new technologies for automatic fixture preparation and NC data generation, using flexible manufacturing systems should lead to high-efficiency manufacturing for small batches. Fixture-free machining, especially for block-like and plate-like components, was considered, and new machining centers were developed. The machining centers require CAD/CAM systems to automatically generate NC programs. By combining the machining centers and CAD/CAM systems, fully automated manufacturing can be performed for block-like and plate-like prismatic components. Research on fixture CAD/CAM systems to support the design of fixtures for complex prismatic workpieces, such as welded, forged, and cast materials, is also discussed.

Keywords: Flexible Manufacturing Systems, CAD/CAM, CAPP, Automated CAM Process, Fixture-Free Machining

Impact of Resequencing on Parallel Assembly Systems, Anant Kumar, Haresh Gurnani, Sunder Kekre, pp. 109-117

This paper considers the effect of resequencing on performance of flexible parallel assembly systems in terms of throughput and work in process. Results show the relationships between different system parameters that can be used to trade off capital and operating costs. Using a first-come first-serve policy (which is adopted in practice), an algorithm determines the effect on throughput of given system parameters, such as number of parallel stations, number of carriers, and size of the resequencing bay. Strategic implications for design of such systems are discussed based on performance results obtained from simulation.

Keywords: Assembly Systems, Flexible Assembly, Parallel Assembly, Resequencing, Throughput, Variability

A Perspective on New Paradigms in Manufacturing, John A. Buzacott, pp. 118-125

Recent attempts at improving manufacturing through such approaches as just-in-time, total quality management, and time-based competition can all be viewed as ways to make manufacturing better able to cope with disturbances and variability. This suggests that manufacturing will evolve either to *integrated* systems relying on computer-based preplanned responses or to *cooperative* systems relying primarily on people for opportunistic problem solving. Implications for manufacturing organizations and for education and research are also discussed.

Keywords: Integrated Manufacturing, Cooperative Manufacturing, Scientific Management, Just-in-Time, Variability

Comment on Optimum Constrained EOQs for Multiple Products with Space Restriction, Katsundo Hitomi, pp. 126-128

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An exact derivation is presented for the optimal solution to the multiple-product constrained economic order quantity (EOQ) problem with space restriction. In this analysis, the space restriction is formulated with inequality rather than with equality, and the Kuhn-Tucker necessary condition is applied instead of the traditional Lagrangian method to obtain the optimal solution.

Keywords: Economic Order Quantity (EOQ), Kuhn-Tucker Necessary Condition, Lagrange Multiplier, Optimization

Single-Step Superfinishing Using Hard Machining Resulting in Superior Surface Integrity, C.R. Liu, S. Mittal, pp. 129-133

Presented are the concept and feasibility of using a single-step hard turning process for superfinishing surfaces that are comparable to bearing races. The following surface integrity requirements of the class of surfaces similar to bearing races are shown to be producible: (1) surface roughness less than 7 µin., (2) surface waviness less than 60 µin., (3) cross-sectional crown of 70 µin., (4) residual stress induced in machining that is favorable for fatigue life, and (5) surface microstructure alteration that is not detrimental to fatigue life.

Experimental results of 10 specimens show that the best surface roughness is as good as 1.7 µin. and can be further improved by optimizing the machining conditions. Residual stress induced by the single-step superfinish hard turning process is more compressive in magnitude and is distributed to a significantly greater depth than that produced by conventional abrasive-based superfinishing.

Keywords: Surface Integrity, Superfinishing, Hard Turning, Bearings, Single-Step

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Scheduling Single-Gripper Gantry Robots in Tightly Coupled Serial Production Lines: Optimum vs. Push/Pull Concept Based Sequences, F. Frank Chen, Qi Su, pp. 139-147

An optimum schedule for single-gripper gantry robots serving tightly coupled automated serial production lines with deterministic workstation process times is developed. The schedule's performance in an engine block manufacturing line is measured and compared with pull and push rules. The optimum schedule is developed by analyzing the cycle time formula for two and three-workstation production lines and then extending the result for the problem of scheduling a production line with multiple workstations where an optimum schedule is also derived. Experimental results indicate that the optimal schedule exhibited much higher effectiveness as the number of stations in the zone served by the gantry robot increases. Superiority of the optimum schedule is demonstrated in all experimental scenarios, yet the superiority is slightly lessened as gantry robot speed or workstation downtime increase. Expected superiority of the pull rule over the push rule is also confirmed.

Keywords: Gantry Robots, Robot Scheduling, Scheduling, Sequencing

Neural Networks and the Part Family/Machine Group Formation Problem in Cellular Manufacturing: A Framework Using Fuzzy ART, Laura Burke, Soheyla Kamal, pp. 148-159

We apply the fuzzy ART neural network to the part family/machine group formation problem in cellular manufacturing. Previous neural network applications have demonstrated the potential role of competitive learning and adaptive resonance theory (ART) networks in part family/machine cell formation, but they have a number of shortcomings. Fuzzy ART, based on a similarity measure from fuzzy set theory, shows great promise over other approaches. We present results for fuzzy ART applied to several test problems of part family formation and give an extension for systematically generating alternative solutions in the problem domain.

Keywords: Neural Networks, Cellular Manufacturing, Part Family Formation, Group Technology

Heuristic Algorithm for the Tool Movement Policy in Flexible Manufacturing Systems, Chang-Yong Song, Hark Hwang, Yeong-Dae Kim, pp. 160-168

We consider the tool loading problem in flexible manufacturing systems (FMSs) in which each part visits only one machine for its entire process. In these FMSs, if a machine does not have on its tool magazine the tools needed for a part assigned to it, it can borrow tools from other machine(s) or a tool crib or use alternative tools. The problem is to assign parts and tools to machines to minimize the number of tool transfers among the machines. A heuristic solution is developed considering similarity among parts. The heuristic is compared with an optimal solution (for small-sized problems) and with an existing heuristic (for medium to large-sized problems). Also, presented are computational results that show the effects of two tool redundancy policies (using alternative tools and using multiple tools for each tool type) on system performance.

Keywords: Flexible Manufacturing Systems, Loading and Scheduling, Scheduling and Sequencing Techniques, Heuristic Methods

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An Industrial Model Based Computer Vision System, Michael Magee, Steven Seida, pp. 169-186

The model-based vision system described performs model-based reasoning at real-time (or near real-time) rates and with low hardware and prototyping costs. A set of useful features is extracted from observed models using a library of feature-extraction operators. Scale and orientation-invariant combinations of these features are used as indices in a hardware lookup table to establish initial correspondence between similar combinations that will be encountered when examining unknown objects. From initial recognition of an unknown object, evidence for an object in a particular spatial pose is accumulated, giving an initial set of hypotheses. The strongest hypotheses are refined by iteratively hypothesizing previously uninstantiated model/object feature matches and computing a confidence measure associated with the current instantiation set. If confidence increases, the newly hypothesized instantiation is retained; otherwise, it is discarded.

The system has been implemented and tested on a SunSparc 2 workstation hosting a DataCube image processing system using a variety of model objects and feature-extraction primitives. Results show that real-time operation and rapid prototyping are achievable, particularly where there are at least a few unambiguous model-feature combinations.

Keywords: Image Processing, Model-Based Vision, Object Recognition, Spatial Pose Estimation

Principles of Open-Architecture Manufacturing, Paul K. Wright, pp. 187-202

General principles of computer-integrated manufacturing are discussed in the context of specific technologies that create flexible factory systems, rapid part realization, and in-process quality assurance. Manufacturing languages, common data structures, compatible operating systems, and common bus structures for machine tools and other processing agents in the factory are seen to be key elements of success. The ability to rapidly convert design ideas to precision mechanical parts is presented as a rapid prototyping case study that highlights the various principles involved in open-architecture, computer-integrated manufacturing.

Keywords: Open Architectures, CAD/CAM, CIM, Rapid Prototyping, Rapid Part Realization, Machine Tools, Sensors, Fixturing, Operating Systems

Design and Operation of Large Systems, Nam P. Suh, pp. 203-213

Issues related to the design of large systems are explored based on the axiomatic approach to design. A large system has the characteristic of having to satisfy varying sets of functional requirements (FRs) over its lifetime, some of which are not known a priori. Such a system must therefore be designed to accommodate these varying and sometimes unknown sets of functional requirements. The design must also allow the system to have an expandable database of design parameters (DPs) to satisfy yet-unknown FRs and endow the system with "intelligence" to make correct decisions. The independence axiom and the information axiom are the basis for several theorems that are derived for large systems. These theorems characterize or establish the bounds on the large systems. The implications of these theorems are examined using organizational design and the design of intelligent manufacturing systems as examples. Finally, the human cognitive process, including human creativity, is discussed as an example of a large system.

Keywords: Large Systems, Manufacturing Systems, Design Theory, Optimization

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Design Criteria for Cooperating Robots Assembly Cells, Pacifico M. Pelagagge, Gino Cardarelli, Mario Palumbo, pp. 219-229

A pragmatic approach to aid in designing assembly cells with cooperating robots is presented in this paper. Conditions justifying the use of multiple cooperation have been previously defined. Effort is focused on the appropriate characterization of assembly tasks to help find solutions for solving collision and coordination problems. The laboratory used for experimental studies on cooperating robots is also illustrated. The presented criteria are applied to the cell setup of a mechanical assembly process.

Keywords: Cooperating Robots, Assembly Automation, Robot Control, Systems Integration

Concentric Design of Robotic Assembly Systems, Hubert K. Rampersad, pp. 230-243

Traditional design methods generally demand much effort, long throughput times, and high costs. For this reason, implementation of new efficient design strategies is becoming increasingly necessary. With application to robotic assembly, a concentric design model is introduced in which there is a parallel and continual iterative interaction between product, process, and system design. The model is used to develop a system layout for the assembly of a power plug assortment.

Keywords: Concurrent Engineering, Design Process, Design for Assembly, Robotic Assembly

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Fuzzy Clustering Procedure for Evaluation and Selection of Industrial Robots, Moutaz Khouja, David E. Booth, pp. 244-251

This paper proposes a decision model for the robot selection problem using fuzzy cluster analysis. Unlike most other models for robot selection, this model considers the fact that a robot's performance, as specified by the manufacturer, is often unobtainable in reality. Robots selected by the proposed model become candidates for factory testing to verify manufacturers' specifications. The proposed model is tested on a real data set and an example is presented.

Keywords: Industrial Robots, Fuzzy Clustering, Decision Models, Robot Selection, Repeatability

Intelligent Workstation Controller for Computer Integrated Manufacturing: Problems and Models, Hyunbo Cho, Richard A. Wysk, pp. 252-263

A shop floor control system (SFCS), an integrated part of computer integrated manufacturing, oversees the production required to fill orders. To effectively control these activities, it is necessary to define a control architecture and functional perspective of how a SFCS operates. In this paper, a hierarchical SFCS (shop, workstation, equipment) is adopted. The objective of the paper is to present the problems and models necessary to develop an intelligent workstation controller (IWC) at the middle level of a SFCS. The IWC is responsible for selecting a specific process routing, allocating resources, scheduling and coordinating the activities across the equipment, monitoring the progress of activities, detecting and recovering from errors, and preparing reports. The IWC fulfills this responsibility using three functions (that is, planning, scheduling, and execution). The requirements for the development of the IWC are to create a process plan representation model, to specify the evolution of a process plan from the shop down to the equipment, and to define all the functions to be integrated into an intelligent controller. A deadlock detection and resolution model is also presented to maintain the system in a deadlock-free state. Finally, the IWC software is created to demonstrate the architectural linkages with other controllers. As a result, the development of the IWC will save cost and time in developing control software for automated manufacturing systems.

Keywords: Intelligent Workstation Control, Shop Floor Control, Flexible Manufacturing Systems, Process Plan

Optimization of Mechanical Assembly Tolerances by Incorporating Taguchi's Quality Loss Function, Bor-Wen Cheng, Saeed Maghsoodloo, pp. 264-276

In an end-to-end mechanical assembly, optimization of tolerance allocation is a critical issue. Many papers have concentrated on minimum cost-tolerance allocation without considering the quality of the final assembly. The objective is to examine the optimal tolerance allocation by considering both tolerance cost and quality loss so that the total assembly cost is minimized. In this paper, a sensitivity analysis is also conducted to determine the effects of shifts in a component's mean and variance. We find that if a component's mean varies, only the quality loss associated with that component will be changed. If a component's variance shifts, the optimal allowance, tolerance costs, and quality losses associated with each component will be affected.

Keywords: Mechanical Assembly, Tolerance Allocation, Cost- Tolerance Function, Taguchi's View of Quality

Design of Material Flow Networks in Manufacturing Facilities, J.W. Herrmann, G. Ioannou, I. Minis, R. Nagi, J.M. Proth, pp. 277-289

In this paper we consider the design of material handling flow paths in a discrete parts manufacturing facility. A fixed-charge capacitated network design model is formulated, and two efficient heuristics are proposed to determine near-optimal solutions to the resulting NP-hard problem. The first heuristic iteratively adjusts the arc fixed costs and selectively includes arcs in the flow network until a feasible network is obtained. The second heuristic partially explores the problem state-space. Both heuristics are tested against an implicit enumeration scheme used to obtain optimal solutions for small examples. For more realistic cases, solutions are compared to lower bounds obtained by linear programming relaxation of the mixed integer program or by an iterative dual-ascent algorithm. Results indicate that, on average, the heuristics provide good solutions in reasonable time. The proposed methodology is applied to design flow paths of an existing manufacturing facility. The role of the flow path network problem in integrated shop design is also discussed.

Keywords: Manufacturing Systems Design, Material Handling, Facilities Design, Heuristic Methods

Scheduling and Order Release in a Single-Stage Production System, James R. Ashby, Reha Uzsoy, pp. 290-306

We develop a set of scheduling heuristics that integrate order release, group scheduling, and order sequencing for a make-to-order manufacturing facility organized into group technology cells. The procedures take into account both order due dates and sequence-dependent setup times. Simulation experiments are used to compare the performance of the procedures to current practice. Results show

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that the new scheduling policies, which consider setup times as well as due dates in both order release and job sequencing decisions, substantially improve due date performance and show that both order release policies and dispatching rules have significant effects on system performance.

Keywords: Loading and Scheduling, Production Control

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Data Extraction from Geometric Models for Process Planning for Parallel Machines, Derek Yip-Hoi, Debasish Dutta, pp. 307-318

Process planning bridges the gap between design and manufacturing. In computer-aided process planning (CAPP) systems, the goal is to automatically extract data from a design model and use it for generating plans for manufacturing. The extracted data should correspond to the type of machining process under consideration, and the extraction techniques must work with the computer-aided design (CAD) model representation. We consider manufacturing information/data extraction from geometric models for parallel machines, particularly mill/turn machines. These are a new class of powerful numerically controlled machine tools with parallel machining capabilities, including turning and milling operations. In this paper, we outline methods for (1) computing the machining axis for a part and (2) determining turning volumes for machining. Examples are included for both methods.

Keywords: Computer-Aided Process Planning, Mill/Turn Machines, Parallel Machining, Machining Axis, Turning Volumes

Partial Visibility for Selecting a Parting Direction in Mold and Die Design, Lin-Lin Chen, Shuo-Yan Chou, Tony C. Woo, pp. 319-330

Selection of an optimal parting direction in mold and die design is considered. Based on the condition for demoldability, two levels of visibility complete and partial are defined for a surface. If a surface is completely visible along a certain direction, it can be separated from the mold along the opposite direction. If a surface is not completely visible and therefore cannot be separated from the mold along any direction, it can be decomposed into portions that are separable and into portions that become undercuts by considering directions in which the surface is partially visible. Algorithms are given for computing the undercut volumes of a polyhedral surface with respect to a particular parting direction and for selecting a parting direction that minimizes the number of undercuts.

Keywords: Injection Molding, Die Casting, Geometric Modeling, Computer-Aided Design, Computer-Aided Manufacturing

Integrated Simulation, Error Assessment, and Tool Path Correction for Five-Axis NC Milling, Yunching Huang, James H. Oliver, pp. 331-344

A system of algorithms is presented for material removal simulation, dimensional error assessment, and automated correction of five-axis numerically controlled (NC) milling tool paths. The methods are based on a spatial partitioning technique that incorporates incremental proximity calculations between milled and design surfaces. Hence, in addition to real-time animated five-axis milling simulation, milling errors are measured and displayed simultaneously. Using intermediate error assessment results, a reduction-of-intersection-volume algorithm is developed to eliminate gouges on the workpiece via tool path correction. A similar technique is implemented for detection and elimination of unexpected collisions between the tool assembly and the workpiece. These combined algorithms provide efficient, accurate, and automatic assessment and correction of five-axis milling tool paths. Finally, the view dependency typical of previous spatial partitioning based NC simulation methods is overcome by a contour display technique that generates parallel planar contours to represent the workpiece, thus enabling dynamic viewing transformations without reconstruction of the entire data structure.

Keywords: Numerically Controlled Milling, Computer-Aided Manufacturing, NC Milling Simulation, NC Verification

Efficient Sampling for Surface Measurements, T.C. Woo, R. Liang, C.C. Hsieh, N.K. Lee, pp. 345-354

The number of samples is directly proportional to the time taken during inspection, while the error due to discretization relates to the quality of the process. This paper investigates two deterministic sequences of numbers, as sample coordinates, by presenting their computations and their applications to metrology. Results show a dramatic improvement in both the number and the error for measurement.

Keywords: Coordinate Measurement, Sample Point Distribution, Discrepancy, Hammersley Sequence, Halton-Zaremba Sequence

Path Planning with Offset Curves for Layered Fabrication Processes, R.T. Farouki, T. Koenig, K.A. Tarabanis, J.U. Korein, J.S. Batchelder, pp. 355-368

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Construction of families of equidistant offset curves as a strategy for filling plane areas is discussed in the context of path planning for rapid prototyping or layered manufacturing processes. Whereas the offset computations for piecewise-linear/circular boundary curves are elementary and hence comparatively robust in implementation the extension to freeform curvilinear boundaries has been frustrated by the absence of exact (that is, rational) offset representations that are compatible with established CAD system standards. Recent mathematical developments offer a resolution to this dilemma, thereby promising significant enhancements in the accuracy and speed of offset computations based on analytic solid model representations.

Keywords: Rapid Prototyping, Layered Fabrication, Path Planning, Offset Curves, Pythagorean-Hodograph Curves

Automated Process Planning for CNC Machining of Spherical Space-Frame Nodes, Y.S. Wong, Z.Y. Wang, pp. 369-377

Space-frame nodes are joints connecting linear members in complex space frames. Each spherical node has a particular hole configuration that defines the orientation of the bolt holes used to connect the space-frame members. The hole configurations are determined by CAD software for space-frame design. Nodes with the same hole configuration vary in number depending on the design of the space frame. A computer-automated machining cell has been implemented to batch manufacture the spherical nodes. The machining cell consists of a three-axis vertical machining center interfaced with a two-axis CNC rotary table. To reduce changeover time between the machining of batches, produce consistent and reliable NC programs, and minimize manpower required to run the cell, a PC-based computer-automated process planning system has been developed to directly translate geometric data from the CAD software to NC programs without intervention by the operator. An important consideration in the process plan for the machining of the space-frame node is the transformation of the CAD-defined bolt hole configuration to a mounting-hole-referenced configuration that minimizes setup and mounting hole requirements. Based on the optimal mounting-hole-referenced configuration, NC toolpaths are derived and corresponding NC programs are generated. This paper presents the approach to determine the optimal mounting-hole-referenced configuration and the operation of the automated process planning system that is suitable for the machining of spherical parts.

Keywords: Flexible Manufacturing Cells, Process Planning, Setup Reduction

Investigation of Characteristic Measures for the Analysis and Synthesis of Precision-Machined Surfaces, Irem Y. Tumer, R.S. Srinivasan, Kristin L. Wood, pp. 378-392

Error prediction and control are key factors in precision machining. These factors rely on the development of formal approaches for analyzing and characterizing error sources in manufacturing. One such approach is the development of mathematical measures of precision, where precision, in this context, is defined as surface variations of manufactured part profiles. In this paper, we discuss a novel investigation of four mathematical measures. These four methods, namely the autocorrelation function, the Fourier spectrum, a fractal-wavelet representation, and the Karhunen-Loève expansion, are applied to surfaces produced from grinding processes. The first two methods provide a basis for the investigation, as they are commonly used in the literature for qualitative signal characterization of manufacturing surfaces. However, the fractal-wavelet method and Karhunen-Loève expansion have never been applied to the analysis and synthesis of surface variations. While other fractal methods have been used to characterize surface-finish variations, a wavelet formalism is a new approach, especially at the scales of *both* surface finish and tolerances. A combination of the first three techniques is shown to give a proper minimum set of characteristic precision measures for representing grinding surfaces. This combination is a clear contribution to the field of analysis of surface characteristics. It is also shown that the Karhunen-Loève technique is a novel alternative to represent surface errors. The existence of characteristic measures of surface precision should aid designers in choosing process and design parameters and in comparing the precision between competing machining processes.

Keywords: Manufacturing Surfaces, Surface Analysis, Surface Synthesis, Characteristic Measures, Precision

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A Data Representation Scheme for Sheetmetal Parts: Expressing Manufacturing Features and Tolerance Requirements, Amy J.C. Trappey, C.-S. Lai, pp. 393-405

Designers and manufacturers in the sheetmetal industry have a particularly strong need for finding data representation schemes that can increase the efficiency and effectiveness of sheetmetal production. Previous research in the area can hardly be applied because shapes and processes of sheetmetal parts are quite different from the most-studied metalcutting parts. In this paper, a unique process-driven, feature-hierarchical data representation scheme is proposed.

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We develop a scheme for sheetmetal parts so that a designer can use the process-related feature hierarchy to describe them and at the same time express design intention and tolerances. Features can be classified into two types. One is called the master feature, which is used to represent the primary profiles of sheetmetal parts. The other type is called the manufacturing feature, which represents a single sheetmetal manufacturing process. Primitive features are defined to represent the manufacturing features. Compound features can be defined by combining primitive features to fulfill a specific design intention. To present a sheetmetal part design that is ready for processing, assembly, and inspection, the geometric and dimensional tolerance information is added to the feature definition. The data structure for the scheme is developed considering the topology, geometry, and tolerance data. Finally, a prototype system called SMCAD is implemented using the solid modeler ACIS to demonstrate the proposed sheetmetal design scheme.

Keywords: Sheetmetal Design, Feature-Based Design, CAD, Solid Modeling

A Dimension and Tolerance Data Model for Concurrent Design and Systems Integration, Shaw C. Feng, Yuhwei Yang, pp. 406-426

This paper introduces a dimension and tolerance data model developed for the foundation of ISO 10303 Part 47. This model is a component of an overall product data model. The model has three major components: dimension schema, tolerance schema, and datum and shape aspect schema. These schema specify data resources and structure for describing dimension and tolerance characteristics of products. Based on this model, descriptions of dimensions and tolerances of products can be communicated between tolerance-related software application systems.

Keywords: STEP, Computer-Aided Design, Data Exchange, Data Model, Dimension Model, Dimension Representation, Dimensioning and Tolerancing, Integration, Geometric Tolerance, Product Data, Tolerance Model, Tolerance Representation

Availability/Reliability Engineering Analysis of Three, Four, and Five-Stage Unreliable Series Transfer Lines, Thomas F. Hassett, Duane L. Dietrich, pp. 427-438

Previous reliability or availability analysis of series transfer lines employed continuous-time Markov chain models. The analysis here focuses on recent developments in discrete-time Markov modeling of lines with unreliable workstations and nonfailing buffers.

Specifically, this paper demonstrates a more stable and efficient computation of stationary-state workstation buffer model probabilities for unreliable lines. In addition, a highly efficient algorithm was developed to isolate and remove transient states from the model. Finally, a regression analysis linear model was developed to predict the effects of changing individual workstation availabilities and buffer capacities on overall line availability.

Keywords: Unreliable Series Transfer Lines, Markov Models, Regression, Availability

An Economic Evaluation Model for Advanced Manufacturing Systems Using Activity-Based Costing, Chan S. Park, Gyu-Tai Kim, pp. 439-451

Recent manufacturing experience suggests that the assumptions of stable product and mass production are no longer valid for advanced manufacturing systems (AMSs). Thus, manufacturing companies have reduced their dependence on traditional cost accounting (TCA) systems by exploring activity-based cost (ABC) systems. Because TCA and ABC systems have different means of handling overhead costs, they may also have differences in their estimates of cash flows with cost accounting data. We will develop costing procedures for various manufacturing activities under ABC systems, and these procedures are incorporated into the proposed multistage investment decision model. Finally, a case study is presented, and we conclude that opportunity costs such as waiting activity and idle activity play more critical roles than the right choice of cost accounting system in justifying investment in an AMS.

Keywords: Manufacturing Economics, Investment Decision, Activity-Based Costing, Economic Analysis

Manufacturing in the Pharmaceutical Industry, Panos D. Sarantopoulos, Tayfur Altiok, Elsayed A. Elsayed, pp. 452-467

This paper overviews the pharmaceutical industry from a manufacturing perspective. Summarized is the current state of the industry within the U.S. as well as in other countries with significant pharmaceutical manufacturing activity. Various classifications of pharmaceutical products and processes, the concept of biotechnology, and the role of the FDA are briefly introduced. Results of a recent benchmarking study and research issues related to pharmaceutical manufacturing are presented.

Keywords: Pharmaceutical, Manufacturing, Benchmarking, Productivity

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